DEVELOPING MINI-APPLICATION ON AUTOMATIC CONTROL WITH INTERDISCIPLINARY TEAMS.

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Abstract ∞ . *We developed an interdisciplinary course to train different engineering branches students in teamwork. We found that the application we asked to develop played a central role in the success or failure of the course. The application has to be complex enough to avoid a birds of a feather approach, but it has to be completed in a standard semester work time. We decided to follow a well defined project life cycle model as the axis to develop teaming skills and as an overall structure of the project. We used the TIDEE guidelines to develop teaming skills. As a result we found ourselves involved in a capstone design course with changing faculty roles as the project progresses.*

Index Terms ∞ *Interdisciplinary experiences, soft skills, teaming, capstone course.*

INTRODUCTION

The society perceives engineers to be technically competent with good math and science skills. However, society does not necessarily believe that engineers have good communication skills. In other words, the stereotype exists that engineers do not need to have good oral skills since they do not work with a lot of people. Clearly, this is an incorrect perception, but it nevertheless it exists.

Traditionally engineering education starts with a common core of math, science and basic engineering knowledge. This common background gives students a foundation for advanced studies in different but related areas of engineering.

Present time projects, on the other hand, require the cooperation among these different branches; but this cooperation is seldom addressed in undergraduate courses.

In order to overcome these teaming skills education deficit, we decided to transform an elective course in a capstone course which aims to show students the big picture of an engineering project. In the paper we present the project life cycle we use in the course, and how we use it as the integration axis of an interdisciplinary experience.

PROJECT'S LIFE CYCLE AND TEACHING MODEL

Modern project management departs from simple ongoing, repeated operations to a scenario where there is less certainty about anticipated outcomes. In more traditional project management, management procedures rely on centralized decision making and strict adherence to hierarchical authority.

In the teaching-learning arena, this management practice has its complement in the way traditional project assignment are conceived. The centralized decision making model is called teacher centered model [1], where every important design decision is made by the faculty (or following the faculty's ideas) and the student is expected to discuss and follow the faculty's directions. As a result, the experience of faculty leads generally to well finished and clean design, but the students are not allowed to follow their owns ideas and are in some sense "protected" from failure. Unfortunately, this way may also prevent students to develop an attitude of learning from their failures, which is considered a central path in building experience [2].

When adaptability and rapid response to change are called for, such as in the volatile present technological market, more complex and adaptive forms of organization and management are required, expanding considerably the degree of decentralization. Such an approach is sometimes called a systems approach [3]. An important aspect of the system approach to a project is the concept of life cycle. It is the basic pattern of change that occurs from beginning to end and that is similar in for all projects.

In the teaching-learning process, this management style can be mapped to a student centered model [4] where students are challenged to follow their own decision using faculty as consultants or facilitators of their design experience. To put the student centered model in action, some structure must be followed in order to achieve a measurable (or gradable) work. The project life cycle is a way of logically ordering the activities of the project and provides a control scheme for the assignment.

The project life cycle used as a model in the assignments had four phases: Conception, Definition, Acquisition and Operation.

For the Conception and Definition phases, students are asked to write a *Request for Proposal* to outline the idea and to state the objectives, scope, specifications and constrains. They answer the R.F.P. with a *Feasibility Study* which is used as a control point and a *Proposal.* As we will describe in the next section, these documents are used to develop some teaming skills. After writing the *Proposal*, teams are ready to enter their Performing stage and the Acquisition phase begin.

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During this phase, students are asked to make a detailed project planning. They have to get the *User Requirements* describing what the user wants the finished system to be and do. Using this document, the final product will be evaluated as acceptable or not. It is a refinement of the R.F.P. and some changes to the original *Proposal* are included to test the adaptability of the teams. The *User Requirements* is used to derive another set called the *System Requirements,* where requirements are stated in technical jargon. By having teams write this document, we aim to develop a common technical language among specialties and to have each one understand the whole project. After writing the documents, the actual system design begins. We asked for the complete technical documentation depending on the specific project, including economic profiles such as return of investment, personnel training plans and maintenance procedures.

Depending on the complexity of the project, the availability of materials and the economic possibilities, the artifact has to be actually built in a whole, or some mix of simulation and building is asked. During a presentation, the team has to explain the operating procedures and identify maintenance issues and improving opportunities.

INTERDISCIPLINARY TEAMING

The project is developed using the TIDEE competencies [5]. TIDEE is an acronym for Transferable Integrated Design Engineering Education. TIDEE is a multi-university project supported by National Science Foundation. The TIDEE project focuses on the first two years of engineering design education in the state of Washington, and focuses on the improvement of both educational methods and materials used to prepare students for engineering design and practice. It can be described as an outcomes-based approach to engineering education and uses structured teams for learning and performing engineering design and is used as a model within the first and second courses. Using the TIDEE competencies as a guide, students learn to work together.

TIDEE identifies three major categories of competencies are required for team-based engineering design: design process, teamwork, and design communication.

The design process is further divided in six distinguishable elements. This elements are:

❖ Gathering information relevant to a need or opportunity,

❖ Definition of the problem establishing product requirements.

❖ Creating alternative solution concepts to address the requirements.

❖ Evaluation and decision making by analyzing options and selecting the ones best meeting requirements.

❖ Interpreting and synthesizing information and decisions an taking action to convert these decisions into deliverable products.

❖ Managing, evaluating, and improving design activity to use information and resources to achieve design objectives optimally.

The selected Project Life Cycle approach allowed to use these elements as control points by mapping then in the deliverables.

Teamwork is the second category of competencies required for effective performance of team-based engineering design. This encompasses capabilities associated with managing the personnel involved in a project to achieve the performance expected from effective teams.

Bruce W. Tuckman [6] stated that a group of people goes through well-defined developmental stages so as to becomes an effective team.

❖ In the forming stage, people act in a socially appropriate manner. They tend to focus on their territories and do things the established way.

❖ In the storming, team conflict begins. People are busy having differences and learning how to deal with them. They begin to gain confidence bringing up issues without going on the attack and blaming others. They also learn to listen to other's concerns without going on the defensive and counterattacking. Successfully dealing with conflict gives the team member a sense that they can bring problems to the group, and that the group will deal with them.

❖ In the norming phase people are able to put issues out for group consideration, and the group established ground rules and its own norms for acceptable behavior.

❖ In the performing stage the group can diagnose and solve problems.

To help students form effective teams and deal with the different stages in every class we scheduled some previous labs and lectures before they began with the project. We used the two first stages of the Life cycle to have teams pass the forming and norming stages.

Design-related communication comprises the third category of the TIDEE competencies for team-based engineering design. This category addresses capabilities associated with managing the information and its transfer during completion of a design project. A final presentation of the teams was scheduled to address this goal.

We did not use the TIDEE suggested scoring schema to asses the level of competency achieved.

THE MINI APPLICATIONS APPROACH

To avoid a sense of failure due to the complexity of a modern standard application, we choose to use mini applications that hopefully can be completed in a standard semester work time. In past experiences we used full blown applications asking students to develop only a part of it, but the winners or losers mood of the society induced a feeling of failure that prevented teams to evaluate positively what they learned. In fact, this is part a common underestimation of the present day everyday technology complexity.

To develop the subjects program, the mini applications have to be built using a distributed layered approach, using sensors and actuators at the field level, controlled by Programmable Logic Controllers (PLC). The PLC are integrated in cells communicated by a Fieldbus and some supervisory work is done using the Web in a conventional computer network. This basic structure allows to form teams with Electronic, Electric, Industrial and Computer Engineering students. Achieving a positive interdependence among different fields students is not easy and a carefully planned teaming set of activities was developed after some failures. An account of these activities is found in [7].

The chosen application is central to teaming efforts. It must provide a highly effective means of turning abstract ideas into project realities and difficulties, supporting a vast array of concepts to be taught and skills to be developed. In a similar effort, the Texas A & M implemented a Real-Time Lab, equipped with a model railroad system and five networked Linux-based control computers, two ActivMedia Pioneer class and two ActivMedia AmigoBot autonomous mobile robots, and 10 LEGO MindStorms robot kits [8] in order to excite student interest and provide an integration axis for different subjects. We choose industrial networks as the integration axis.

The industrial network technology applies the multiple advantages of the well-known OSI model [9] in automation. This fact is useful not only to explain the control concepts, but as a pedagogical tool. The cleanness of the layer model aids to understand the cooperation among different devices with well-defined functions.

The layered architecture calls for a well-structured and defined way of presenting the material in an undergraduate course. It also allows different abstraction levels, according on how the different engineering fields view the automation. This helps to integrate students from different field disciplines, in the same way that the industrial networks integrate different devices to deploy a complex field control, communication and control network. In this way, Industrial Engineers see the industrial networks as the integrating automation device they need for their processes, considering them at the application level and concentrating their interest in requirements' specification. Electronic Engineers are interested in sensors and actuators, so they deal with the physical and data link layers in order to interconnect the devices. Communication Engineers take care of the factory network integration and it connection with CAD, CAM, inventory and logistic applications. Software Engineers assure the work of layers 4 to 7, and integrate or develop applications in order to get the information properly presented to the user, e. g. using the enterprise intranet and the requirements specification. Control Engineers design the overall control and monitoring applications to meet the industrial specification.

As a grading objective, each student shall acquire the necessary skills to understand the system as a whole, and to implement a similar subsystem in her/his engineering field. And the instruction to the students is to convince the examiner in a public presentation that this objective is meet. This evaluation schema introduces students to the complex topic of public presentations, and faculty is required to do some preparation work regarding it.

The spectrum of mini applications used in the courses varies a lot. Some of the examples are automating filling facilities, bottling and boxing of fluids, hydroponic growing of industrial chili (used in cosmetics), water treatment and plastic packaging. Each one developed in an special environment with facilities, labor, communications and services corresponding to different places of Argentina.

CONCLUSIONS

By using Mini Applications, students become involved in problem management, instead the common approach of *closed* problem solving. This attitude emphasizes the fact that the design of a solution is only a stage in the project life cycle.

Understanding and interpreting the environment where the project will be developed plays a key role in the design process. students have to solve "secondary" issues as qualified labor availability vs. in house training or third part hiring of services vs. in house providing. By developing "parts" of a big project, these problems were neither identified nor addressed.

The rol of faculty changes during the different team stages. Initially, before the students are able to develop a shared understanding of what to do and how to do it, teachers have to play the rol of a project leader. As students gain control of the project, teachers become more a consultant and sometimes a customer to give some feedback ideas on functionality, structure and other project characteristics.

As every student centered experience, it implies a lot of work for faculties and a love it or hate it answer of students. Some of them argued they felt really identified with the engineering task and some of them were more comfortable with the "closed problem" approach and complained about faculty not having the problem well defined.

REFERENCES

[1] Catalano, G. "Transformation: From Teacher-Centered to Student-Centered Engineering Education" *Frontiers In Education (FIE) 1997*, Session T1G. Pittsburg, PA, USA, 1997

[2] Knight, J., Upchurch,R. "The acquisition of expertise in Software Engineering

Education",*Frontiers In Education (FIE) 1998*, Session S4E. Tempe, AZ, USA, 1998.

[3] Nicholas, J.," *Management Business and Engineering Projects,* Prentice Hall, 1990, pp. 89

[4] Jacobson, D., Davis, J., Licklider, B. "See one, do one, teach one...", *Frontiers In Education (FIE) 1998*, Session F3B. Tempe, AZ, USA, 1998.

[5] http://www.tidee.cea.wsu.edu/ (30/01/03)

[6] MacKey, K., "Stages of Team Development", *IEEE Software,* Vol. 16 No 4., 1999, pp. 90-91.

[7] Feldgen, M., Clua, O., Ferreira, F. "An Interdisciplinary Teamiong Laboratory on Industrial Networks"", Frontiers In Education (FIE) 2002, Session F4F. Boston, Ma, USA, 2002

[8] Dannelly, R. S., Michaud, P., Patterson-McNeill, H., Steidley C. W., "A Multidisciplinary Student-Centered Laboratory", Frontiers In Education (FIE) 2002, Session T2D. Boston, Ma, USA, 2002

[9] Rose M. T., *The Open Book, A Practical Perspective on OSI*, Prentice Hall, 1990.